Chem 12- Notes on Acids & Bases

After Tutorial 14 & Workbook Questions 10-19 p. 115-121
Do demo of Conductivity 1 M HCl, 1 M CH₃COOH

Strong & Weak Acids & Bases

**Strong Acid** - An acid which is **100% ionized in a water solution**.

E.g.) HCl\(_(g)\) + H₂O\(_(l)\) → H₃O\(^+\)\(_{(aq)}\) + Cl\(^-\)\(_{(aq)}\)

**Question:** What is the [HCl\(_(g)\)] in 1 M HCl?

**Answer:**

**Question:** What is [H₃O\(^+\)] in 0.20 M HCl

**Answer:**

**Important:**

**In a Strong Acid** [H₃O\(^+\)] = [Acid] (to Start with)

E.g.) What is [H₃O\(^+\)] in 0.60 M HNO₃

**Answer:**

**Weak Acid:** An Acid which is **less than 100% ionized in solution**.

(In Chem 12 WA’s are usually significantly less than 100% ionized.)
(Usually < 5% ionized)

- In a solution of a weak acid, most of the molecules don’t ionize.

E.g.) HF\(_(g)\) + H₂O\(_(l)\) ⇋ H₃O\(^+\)\(_{(aq)}\) + F\(^-\)\(_{(aq)}\) \(\leftrightarrow\) ions

\(\text{[H₃O}^+\] is only a small fraction of [HF]\)

A beaker containing aqueous HF

NOTE: WA’s can be molecules but they might also be + or – ions.

E.g.) NH₄\(^+\) + H₂O ⇋ H₃O\(^+\) + NH₃

HSO₄\(^-\) + H₂O ⇋ H₃O\(^+\) + SO₄\(^{2-}\)
- Any acid (weak or strong) could have high or low *concentration*.

**Weak & Strong** → refers to % ionization.

**Concentration** → the moles of acid dissolved per litre.

Eg.) 10.0 M HCl → conc. and strong \([H_3O^+] = 10.0 \text{ M}\)
0.001 M HCl → dilute and strong \([H_3O^+] = 0.001 \text{ M}\)
10.0 M HF → conc. and weak \([H_3O^+] = \text{low}\)
0.001 M HF → dilute and weak \([H_3O^+] = \text{very low}\)

**The Acid Table**

<table>
<thead>
<tr>
<th>Strong Acids</th>
</tr>
</thead>
<tbody>
<tr>
<td>HClO₄</td>
</tr>
<tr>
<td>HI</td>
</tr>
<tr>
<td>HBr</td>
</tr>
<tr>
<td>HCl</td>
</tr>
<tr>
<td>HNO₃</td>
</tr>
<tr>
<td>H₂SO₄</td>
</tr>
</tbody>
</table>

*Note H₂SO₄ is a SA but diprotic
- The first ionization is 100% = H₂SO₄ + H₂O → H₃O⁺ + HSO₄⁻
- The second ionization is <100% HSO₄⁻ + H₂O ⇌ H₃O⁺ + SO₄²⁻

<table>
<thead>
<tr>
<th>Weak Acids</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₃O⁺ ⇌ H⁺ + H₂O</td>
</tr>
<tr>
<td>HIO₃ ⇌ H⁺ + IO₃⁻</td>
</tr>
<tr>
<td>.</td>
</tr>
<tr>
<td>.</td>
</tr>
<tr>
<td>H₂O ⇌ H⁺ + OH⁻</td>
</tr>
</tbody>
</table>

Most act as weak acids in water
**Strong Base**

A substance (base) which (ionizes) or dissociates 100% in solution

Forms ions from molecules or atoms

Ions in an ionic solid separate and dissolve in water

**Weak Base**

A base which is less than 100% ionized in solution.

E.g.) \( \text{NH}_3(aq) + \text{H}_2\text{O}(l) \rightarrow \text{NH}_4^+(aq) + \text{OH}^-(aq) \)

- Consists of mostly \( \text{H}_2\text{O} \) and \( \text{NH}_3 \) molecules with a few \( \text{NH}_4^+ \) and \( \text{OH}^- \) ions.

**Using Acid Table & Periodic Table**

**Strong Bases**

\[ \rightarrow \text{OH}^- \rightarrow \text{O}^2- \rightarrow \text{NH}_2^- \]

Strong bases (bottom 3 on right side)

- Any substance which dissociates completely to produce \( \text{OH}^- \), \( \text{O}^2- \) or \( \text{NH}_2^- \) is a **Strong Base**

**Alkali Metal Hydroxides** (Group 1)

\( \text{LiOH, NaOH, KOH, RbOH, CsOH} \) are all highly (100%) soluble and form \( \text{OH}^- \), so they are all **strong bases**.

**Alkaline Earth** Hydroxides (Group 2)

\( \text{Mg(OH)}_2, \text{Ba(OH)}_2, \text{Sr(OH)}_2 \) are designated as Strong Bases (even though \( \text{Sr(OH)}_2 \) is the only one called “Soluble” on the Solubility Table. They dissociate to form 2 \( \text{OH}^- \) s each:

\( \text{Ba(OH)}_2(s) \rightarrow \text{Ba}^{2+}(aq) + 2\text{OH}^-(aq) \)
Chemistry 12
Notes on Unit 4 – Acids, Bases and Salts

What is the \([\text{OH}^-]\) in 0.10 M NaOH?

\[
\begin{align*}
0.10 \text{ M} & \quad 0.10 \text{ M} & \quad 0.10 \text{ M} \\
\text{NaOH}_\text{(s)} & \rightarrow \text{Na}^{+}_\text{(aq)} + \text{OH}^-_\text{(aq)} & \quad [\text{OH}^-] = 0.10 \text{ M}
\end{align*}
\]

What is the \([\text{OH}^-]\) in 0.10 M Ba(OH)_2?

\[
\begin{align*}
0.10 \text{ M} & \quad ____ \text{ M} \quad ____ \text{ M} \\
\text{Ba(OH)}_2 & \rightarrow \text{Ba}^{2+}_\text{(aq)} + 2\text{OH}^-_\text{(aq)}
\end{align*}
\]

For A **Strong Base**

\[ [\text{OH}^-] = \text{[Base]} \times \# \text{ of OH’s in formula} \]

Salts which produce \(\text{O}^{2-}\) and \(\text{NH}_2^-\) are **definitely strong bases**.

E.g.) Quicklime in water: \(\text{CaO}_\text{(s)} \rightarrow \text{Ca}^{2+}_\text{(aq)} + \text{O}^{2-}_\text{(aq)}\)

\[
\begin{align*}
\text{O}^{2-} + \text{H}_2\text{O} & \rightarrow \text{OH}^- + \text{OH}^- \\
\text{(Oxide ion)} & \quad (100\%)
\end{align*}
\]

Or \(\text{O}^{2-} + \text{H}_2\text{O} \rightarrow 2\text{OH}^-\)

Find \([\text{OH}^-]\) in 0.10 M CaO

\[
[\text{O}^{2-}] = 0.10 \text{ M}
\]

\[
(0.10\text{M}) \quad ____ \text{M} \\
\text{O}^{2-} + \text{H}_2\text{O} & \rightarrow 2\text{OH}^- \\
[\text{OH}^-] = ____ \text{M}
\]
Weak Bases
Found above OH on *right* side of Table.

\[
\begin{align*}
\text{H}_2\text{O} \\
\text{IO}_3^- \\
\cdot \\
\cdot \\
\text{PO}_4^{3-} \\
\text{OH}^- \\
\text{O}^{2-} \\
\text{NH}_2^- \\
\end{align*}
\]

*Most* form *weak bases* in water
Why do I say “most”?

Very Weak (non-hydrolyzing Bases) or Spectators
These are the *top 5* (not 6) “bases” on the *right*.

\[
\begin{align*}
\text{ClO}_4^- \\
\text{I}^- \\
\text{Br}^- \\
\text{Cl}^- \\
\text{NO}_3^- \\
\end{align*}
\]

They are so weak that they cannot react with \(\text{H}_2\text{O}\) to form \(\text{OH}^-\)
(They do *not* contribute any \(\text{OH}^-\) to a solution)

For this reason, these top 5 on the right are *not* usually referred to as “bases” in aqueous solution. They are called **Spectators**!

Conj. Bases of strong acids---- In acid-base reactions they are **SPECTATORS**

In a SA, the bond to \(\text{H}^+\) is weak

\[
\begin{align*}
\text{H} + \text{Cl}^- + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^{+} (\text{aq}) + \text{Cl}^- (\text{aq}) \\
\text{So weak , it cannot take an H}^+ \text{ from H}_2\text{O or even H}_3\text{O}^+ \\
\end{align*}
\]

SA’s have non-hydrolyzing (spectator) ions for conj. Bases.
**Amphiprotic Species (ions or molecules)**

- Are found on both sides of the table e.g.) $\text{HSO}_4^-$
- Can act as acids (donate $\text{H}^+$’s) or as bases (accept $\text{H}^+$’s)
- To look at an amphiprotic species as an **acid**, you must find it on the **left** side:

  \[
  \text{e.g.)} \quad \text{C}_6\text{H}_5\text{OH} \quad \text{⇌} \quad \text{HCO}_3^- \quad \text{⇌} \quad \text{H}_2\text{O}_2
  \]

  HCO$_3^-$ is a _________er acid than C$_6$H$_5$OH
  HCO$_3^-$ is a _________er acid than H$_2$O$_2$

- To look at an amphiprotic species as a **base**, you must find it on the **right** side:

  \[
  \text{e.g.)} \quad \text{H}^+ \quad \text{+} \quad \text{Al(H}_2\text{O)}_5(\text{OH})_2^+ \quad \text{⇌} \quad \text{H}^+ \quad \text{+} \quad \text{HCO}_3^- \quad \text{⇌} \quad \text{H}^+ \quad \text{+} \quad \text{C}_6\text{H}_5\text{O}_7^{3-}
  \]

  HCO$_3^-$ is a _________er base than C$_6$H$_5$O$_7^{3-}$
  HCO$_3^-$ is a _________er base than Al(H$_2$O)$_5$(OH)$_2^+$

HSO$_4^-$ in shaded region on top right will **not** act as a base in water (Too weak of a base)
- However, it is **not** a spectator! (like NO$_3^-$ is) Why not?

(\text{HSO}_4^- is also found on the left side quite a way up, it is a relatively “strong” weak **acid**.)

### The Leveling Effect for Acids

What is [H$_3$O$^+$] in 1.0 M H$_3$O$^+$? ______

What is [H$_3$O$^+$] in 1.0 M HNO$_3$? ______

What is [H$_3$O$^+$] in 1.0 M HCl? ______

Acids from HClO$_4$ to H$_2$SO$_4$ are 100% ionized in water

*only solvent used in Chem 12 (and most Chemistry)*

- So even though HClO$_4$ is above HCl on the chart, it is no more acidic in a water solution.

**H$_3$O$^+$ is the strongest acid that can exist in an undissociated form in water solution.**

- All stronger acids ionize to form H$_3$O$^+$
(NOTE: although \( \text{H}_2\text{SO}_4 \) is diprotic, the \( \text{H}_3\text{O}^+ \) produced from the second ionization is very little compared to that from the first)

1\(^{st}\) ionization: \( \text{H}_2\text{SO}_4 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{HSO}_4^- \)

\[ \text{1M(SA)} \quad \text{1M} \]

2\(^{nd}\) ionization: \( \text{HSO}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{SO}_4^{2-} \)

\[ \sim 1\text{M (WA)} \]

The only way you can tell which strong acid is “stronger” is to react them in a non-aqueous (not \( \text{H}_2\text{O} \)) solvent.

\[ \text{Eg) HClO}_4 + \text{H}_2\text{SO}_4 \rightleftharpoons \text{H}_3\text{SO}_4^+ + \text{ClO}_4^- \]

(\( \text{it is found that HClO}_4 \) donates a proton to \( \text{H}_2\text{SO}_4 \), not the other way around, so \( \text{HClO}_4 \) is a stronger acid than \( \text{H}_2\text{SO}_4 \)) \textit{This is not important in Chemistry 12.}

This would \textit{not} happen in a water solution. (In \( \text{H}_2\text{O} \), they would \textit{both} form \( \text{H}_3\text{O}^+ \))

\textbf{Leveling Affects of Bases}

\textit{The strongest base which can exist in high concentrations in water solution is OH\(^-\) The two stronger bases below it will react with water completely to form OH\(^-\).}

\[ \text{Eg) O}^2^- + \text{H}_2\text{O} \rightarrow \text{OH}^- + \text{OH}^- \quad \text{SB} \]

\[ \text{Or} \]

\[ \text{O}^2^- + \text{H}_2\text{O} \rightarrow 2\text{OH}^- \]

What is the final [\( \text{O}^2^- \)] in 1.0 M \( \text{Na}_2\text{O} \)? Answer: 0 M

- \textit{All} the \( \text{O}^2^- \) will react with water to form OH\(^-\)

\[ \begin{array}{c}
\text{1.0M} \\
\rightarrow \text{2.0 M}
\end{array} \]

\[ \text{O}^2^- + \text{H}_2\text{O} \rightarrow 2\text{OH}^- \quad \text{so [OH}^-] = 2.0 \text{ M} \]

Write an equation for \( \text{NH}_2\) reacting with \( \text{H}_2\text{O} \).

Answer: \[ \text{______________________________} \]

- \textit{Do Ex. 21-27 Pg.125-126 S.W.}
**Acid-Base Equilibria & Relative Strengths of Acids & Bases**

- Take out your acid table
- Mix some $\text{H}_2\text{PO}_4^-$ and some $\text{CO}_3^{2-}$

So, in this case $\text{CO}_3^{2-}$ will play the role of base (take $\text{H}^+$) and $\text{H}_2\text{PO}_4^-$ will play the role of acid (donate an $\text{H}^+$).

$$
\begin{align*}
\text{H}_2\text{PO}_4^- + \text{CO}_3^{2-} & \rightleftharpoons \text{HCO}_3^- + \text{HPO}_4^{2-} \\
& \text{(A)} & \text{(B)} & \text{(A)} & \text{(B)} \\
\end{align*}
$$

Consider the 2 acids $\text{H}_2\text{PO}_4^-$ and $\text{HCO}_3^-$

**Question:** At equilibrium, which will be favoured, reactants or products?
They both “want” to donate protons.
- look them both up on the left side

$\text{H}_2\text{PO}_4^-$ is **above** $\text{HCO}_3^-$ on LEFT, so $\text{H}_2\text{PO}_4^-$ is a **stronger** acid than $\text{HCO}_3^-$. 

$$
\begin{align*}
\text{H}_2\text{PO}_4^- & \rightarrow \text{H}^+ + \text{HPO}_4^{2-} \\
\text{H}^+ + \text{CO}_3^{2-} & \rightarrow \text{HCO}_3^- \\
\end{align*}
$$
So the reaction:

\[
\text{H}_2\text{PO}_4^- + \text{CO}_3^{2-} \rightleftharpoons \text{HCO}_3^- + \text{HPO}_4^{2-}
\]

Will have a greater tendency to go right than left and products will be favoured. 
- so find acid on each side. \textit{Equilibrium favors the side with the weaker acid.} 

“\textit{Only the weak survive}” or “\textit{Survival of the weakest}”

“stronger” means a greater tendency to react and change to something else.

\[
\text{H}_2\text{PO}_4^- + \text{CO}_3^{2-} \rightleftharpoons \text{HCO}_3^- + \text{HPO}_4^{2-}
\]

Don’t use terms “strong” and “weak”, 
they have other specific meanings.

Question: Will

\[
\text{HSO}_3^- + \text{HCO}_3^- \rightleftharpoons \text{H}_2\text{CO}_3 + \text{SO}_3^{2-}
\]

Favor reactants or products? 

\textbf{Mixing 2 amphrotic ions} (products not given) 
- complete rx. and tell which is favoured (r or p)

eg.) \[
\text{HSO}_4^- + \text{H}_2\text{PO}_4^- \rightarrow ?
\]

Which will play role of acid? 
(both are capable of being acids or bases)

- First, compare \textit{these two} on \textit{LEFT} side

\text{HSO}_4^- \text{is higher than } \text{H}_2\text{PO}_4^- \text{ on LEFT side so has a greater tendency to act as an acid.}
- Complete the equation: (making $\text{HSO}_4^-$ act as the acid.)

$$\text{HSO}_4^- + \text{H}_2\text{PO}_4^- \rightleftharpoons \text{H}_3\text{PO}_4 + \text{SO}_4^{2-}$$

A       B     A      B

Now compare the 2 conjugate acids (Look fo them both on the LEFT side of chart.) $\text{HSO}_4^-$ is slightly ABOVE $\text{H}_3\text{PO}_4$ on the left side so $\text{HSO}_4^-$ is the SrA and $\text{H}_3\text{PO}_4$ is the WrA.

$\text{HSO}_4^- + \text{H}_2\text{PO}_4^- \rightleftharpoons \text{H}_3\text{PO}_4 + \text{SO}_4^{2-}$ so the products (with WrA,) are favoured!

$\text{SrA}$       $\text{WrA}$

- Comparing relative strengths of bases.

E.g.) $\text{HSO}_4^- + \text{H}_2\text{PO}_4^- \rightleftharpoons \text{H}_3\text{PO}_4 + \text{SO}_4^{2-}$

Base       Base

Compare these on the RIGHT side of table

$\text{H}_2\text{PO}_4^-$ is lower on the right side (stronger base) than $\text{SO}_4^{2-}$

So see:

$$\text{HSO}_4^- + \text{H}_2\text{PO}_4^- \rightleftharpoons \text{H}_3\text{PO}_4 + \text{SO}_4^{2-}$$

$\text{SrA}$       $\text{SrB}$       $\text{WrA}$       $\text{WrB}$

- Since this equilm favoured products ($\text{H}_3\text{PO}_4$ is WrA), we can say that equilm favours the side with the weaker conjugate base.

NOTICE: The SrA is on the same side as the SrB. [the SrA has the weaker conj. Base] The WrA is on the same side as the WrB

(Birds of a feather flock together)

or

(The weakies hang out together and survive better than the “strongies”.)

- So we could compare conj. Acids or conj. Bases.  $\textbf{Equilibrium favors the side with the weaker conj. Acid and the weaker conj. Base.}$
Starting with “Salts”

The amphiprotic ions are often products of the dissociation of salts.  
- Spectator ions must be discarded.

NOTE: All alkali ions Na⁺, K⁺, Li⁺ …etc….. are spectators in Acid-Base reactions. Also top five ions right side of acid chart (ClO₄⁻, I⁻, Br⁻, Cl⁻, NO₃⁻) are spectators in Acid-Base reactions.

E.g.) complete the net ionic reaction between and state whether equilm favors reactants or products

$$\text{NaHSO}_3 \text{ and } \text{K}_2\text{HPO}_4$$

Dissociate

$$\text{(Na}^+\text{) HSO}_3^- \quad \text{(K}^+\text{) HPO}_4^{2-}$$

Spectator ions DISCARD!

$$\text{HSO}_3^- + \text{HPO}_4^{2-} \quad \text{H}_2\text{PO}_4^- + \text{SO}_3^{2-}$$

HSO₃⁻ is higher, so it will play the role of the acid.

$$\text{HSO}_3^- + \text{HPO}_4^{2-} \quad \text{H}_2\text{PO}_4^- + \text{SO}_3^{2-}$$

$\text{SrA} \quad \text{B} \quad \text{WrA} \quad \text{B}$

HSO₃⁻ is a stronger acid than H₂PO₄⁻, so equilm favors the side with the weaker acid (H₂PO₄⁻) so products are favored!
Relating The Keq to A-B equilibria

If products are favored Keq is large (>1)
If reactants are favored Keq is small (<1)

Eg.) Given:

\[ HA + B \rightleftharpoons HB + A^- \quad Keq = 0.003 \]
Which acid is stronger, HA or HB?

Keq is small so reactant side is favored.
Since equil favours side with WrA, HA must be the weaker acid, so HB would be the stronger acid.
- Which is the stronger base? Ans. _______
  (the SrB is on the same side as the SrA)
  or
  (the weaker acid (HA) has the stronger conj. Base (A^-))

-Do Ex. 38 - 46 P. 133 of SW.